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THE DEGRADATION OF NYLON BY IRON RUST

Richard I. Tubis

Naval Aerospace Recovery Facility

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August 1974

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Nylon (both fabric and cord) was exposed to iron rust, Fe_2O_3, and $FeCl_3$, in environments of sea water (synthetic), distilled water, pH4 and pH10. The iron rust and Fe_2O_3 were found to be not significantly chemically degrading to the nylon. The $FeCl_3$ was degrading as expected.

TECHNICAL REPORT NO. 8-74

U.S. NAVAL AEROSPACE RECOVERY FACILITY
El Centro, California

THE DEGRADATION OF NYLON BY IRON RUST

by

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ABBREVIATIONS AND SYMBOLS

cc	Cubic Centimeter
$FeCl_3$	Ferric Chloride
Fe_2O_3	Ferric Oxide
HCl	Hydrochloric Acid
KCl	Potassium Chloride
NaBr	Sodium Bromide
NaCl	Sodium Chloride
NaOH	Sodium Hydroxide
pH	Logarithm of the Reciprocal of the Hydrogen Ion Concentration
σ	Standard Deviation
$\bar{X}_n$	Mean Value of Group n
$\bar{\bar{X}}_n$	Mean of the Means of Group n

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SUMMARY

This test program was conducted to resolve conflicting evidence as to whether or not iron rust is degrading to nylon. Two tests were conducted: the first used 1.1 oz. ripstop nylon and 50-lb. 6-cord; the second used 1.1 oz. ripstop nylon only. The test samples were divided into four groups: control, iron rust, Fe_2O_3 and $FeCl_3$. Each group was divided into five environments: dry, distilled water, salt water, pH4 and pH10. The samples were left in their specific environments for 30 days before being washed, dryed, and tested. It was determined that iron rust does not chemically degrade nylon to any significant degree.

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INTRODUCTION

Many users of aliphatic polyamide nylon cord, webbing, rope, and fabric have formed the opinion that iron rust degrades these articles in service.

An informal test program conducted at the NAVAERORECOVFAC (Naval Aerospace Recovery Facility) appeared to confirm this belief. However, later tests at the NAVAERORECOVFAC and U. S. Army's Natick Laboratories failed to support either the earlier test results or the opinion that iron rust was degrading.

The program reported herein was established in an attempt to resolve these anomalous results.

TEST-MATERIAL-EQUIPMENT-CHEMICALS

The test materials utilized were 1.1 oz. ripstop nylon (type 330) canopy fabric and 6-cord nylon thread both being manufactured from nylon 66 (polyhexamethylene adipamide).

The test equipment consisted of a Fisher Accumet 420 pH meter, twenty 150 cc beakers, 14 one-quart mason jars, an Instron Tensile Tester, plus general laboratory equipment.

The chemicals used included NaOH solution, HCl solution, NaCl, NaBr, KCl, Fe_2O_3, $FeCl_3$, distilled water and iron rust.

METHOD OF TEST

Samples were exposed to five general test environments: (1) dry, (2) wet-distilled water, (3) wet-salt water (similar to sea water), (4) pH4 (HCl solution), and (5) pH10 (NaOH solution).

The latter three environments were prepared as follows: (3) Twenty grams of NaCl, 10 grams of KCl and 2 grams of NaBr were placed in 1000 cc of distilled water and stirred until dissolved. (4) A 1×10^{-4} normal solution of HCl which corresponds to a pH4 solution was prepared. The pH of the solution was taken and it was either diluted or additional acid solution added as needed to obtain approximately a pH4 solution. (5) A 1×10^{-4} normal solution of NaOH which corresponds to a pH10 solution was prepared. The pH of the solution was taken and it was either diluted or additional base solution was added as needed to obtain approximately a pH10 solution. (Note: The acid and base solution must be well stirred otherwise an incorrect pH reading will be obtained).

Test No. 1 One-hundred $1\frac{1}{2}$-inch-wide by 8-inch-long samples of 1.1 oz. ripstop nylon, type 330, and twenty 40-inch-long samples of 50-lb., 6-cord nylon thread were prepared. Five ripstop nylon samples and one thread sample were placed in each of the twenty 150 cc beakers. Five beakers were used as the control group, five as the iron rust group, five as the Fe_2O_3 group, and five as the $FeCl_3$ group. The five test environments for each group included dry, distilled water, salt water, pH4, and pH10.

To place the three chemicals (Fe_2O_3, Iron Rust, and $FeCl_3$) on the samples, each piece of nylon was first wetted with distilled water and then rolled in the powdered chemical. The nylon samples were folded and placed in the appropriate beaker. After the nylon had dried, 30 cc of the designated solution (as shown on the beakers) was added to each beaker and allowed to stand for 30 days. During that time, distilled water was added as required to compensate for evaporation.

After the 30-day period, the samples were washed in a mixture of cold water, Tide, and Avitex AD and then rinsed and dried at room temperature. Each beaker sample group was placed in an individually marked envelope. The samples were environmentally conditioned under standard ambient conditions and their breaking strength determined by means of the Instron Tensile Tester.

Test No. 2: One hundred-twenty $1\frac{1}{2}$-inch-wide by 8-inch-long samples of 1.1 oz. ripstop nylon, type 330, were prepared. The ripstop samples were placed in each of 10 of the 14 mason jars and five samples were placed in each of the other four jars. Five mason jars contained Fe_2O_3, and the remaining four contained iron rust. (Due to the small amount of the original lot of iron rust remaining, only five samples per jar could be used and the pH10 environment was eliminated.)

The final procedure was identical to that for Test No. 1, except the mason jars were sealed; thus, no water had to be replaced due to loss by evaporation.

DISCUSSION

Tables I and II contain tabulated results of Test No. 1 on 1.1 oz. ripstop nylon and 50-lb., 6-cord nylon thread. Individual breaking strength values appear in Appendix A and Appendix B, respectively. The average breaking strength of the ripstop samples for each environment indicated a slight decrease in strength from the controls to the Fe_2O_3 and showed a large decrease to the $FeCl_3$. The iron rust, however, did not follow this pattern even though iron rust consists mostly of Fe_2O_3. Since no significant change was apparent from the control to the rust or Fe_2O_3 as there was to the $FeCl_3$ (a known degrader of nylon), test results were inconclusive. The standard deviations also revealed no specific pattern but remained random.

The 50-lb., 6-cord nylon thread samples showed the same general pattern i.e., slight reduction in breaking strength from the control to the Fe_2O_3. This time,however, the iron rust samples also followed the same pattern. The $FeCl_3$ proved to be degrading as was expected.

Standard deviations of the average breaking strengths for the controls, the rust, and the Fe_2O_3 samples (omitting the $FeCl_3$) were calculated for both the 1.1 oz. ripstop and the 6-cord. All the average breaking strengths were within ± 2 standard deviations (calculated for the three groups as a unit) for the 6-cord, and within ± 2.1 standard deviations for 1.1 oz. fabric. The hypothesis being that they all belonged to the same population group.

To clarify the results obtained, a second test was conducted on 1.1 oz. nylon ripstop using sealable mason jars to completely isolate each sample group from external conditions. Results of this test as shown in Table III, showed no drop in average breaking strength as occurred during the previous test. When standard deviations of the average breaking strengths were compared, they were all well within two standard deviations of the average as would be expected in a normal fabric breaking strength distribution curve. (For individual breaking strengths, refer to Appendix C.)

The majority of average breaking strengths for each test set were found to be slightly lower than the dry control of that set, indicating a detrimental albeit minute effect on the nylon.

Note that the breaking strength of nylon fabric may decrease due to the abrasive properties of powdered iron rust if not removed by washing (references 1 and 2). This may explain the prevalence of the belief that iron rust is degrading to nylon.

CONCLUSION

Although a slight loss in strength may result from prolonged (30 days or more) contact, iron rust cannot be considered as being chemically degrading to nylon to any significant extent. Strength losses noted in service are probably due to physical abrasive action of rust and associated contamination.

RECOMMENDATION

All items of equipment fabricated wholly or partially of nylon and which come in contact with iron rust, should be washed in accordance with reference 3 to remove rust before degradation occurs.

APPENDIX A.

Individual Breaking Strengths
1.1 Ounce Ripstop Nylon-
Test No. 1

Individual Breaking Strengths 1.1 oz. Ripstop Nylon-Test No. 1, lbs.

SAMPLE GROUP	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5
CONTROL-Dry	52.7	51.5	52.0	51.2	51.0
CONTROL-H_2O	52.2	53.2	52.0	53.2	51.2
CONTROL-Salt H_2O	55.2	56.2	45.0	47.0	51.2
CONTROL-pH=4 (HCl)	51.5	52.5	51.2	52.5	51.5
CONTROL-pH=10 (NaOH)	50.7	50.2	48.0	51.2	51.0
RUST-Dry	52.0	47.7	51.2	50.5	53.0
RUST-H_2O	46.0	50.2	48.2	46.7	51.5
RUST-Salt H_2O	54.2	54.5	53.0	55.0	54.0
RUST-pH=4 (HCl)	52.7	53.0	53.2	53.2	51.2
RUST-pH=10 (NaOH)	53.0	48.2	53.0	51.5	49.7
FERRIC OXIDE-Dry	51.2	51.2	52.0	49.0	51.0
FERRIC OXIDE-H_2O	47.0	49.7	50.0	51.0	51.0
FERRIC OXIDE-Salt H_2O	51.5	54.5	41.5	46.5	53.2
FERRIC OXIDE-pH=4 (HCl)	48.5	49.7	50.5	38.7	52.5
FERRIC OXIDE-pH=10 (NaOH)	51.0	46.7	51.2	51.2	50.0
FERRIC CHLORIDE-Dry	32.0	36.0	33.0	39.0	32.5
FERRIC CHLORIDE-H_2O	41.5	31.0	31.5	33.0	26.0
FERRIC CHLORIDE-Salt H_2O	13.7	15.2	17.5	41.2	42.0
FERRIC CHLORIDE-pH=4 (HCl)	34.2	17.5	18.0	40.7	24.5
FERRIC CHLORIDE-pH=10 (NaOH)	20.2	40.5	42.0	13.0	18.0

APPENDIX B.

Individual Breaking Strengths of
50-Pound, 6-Cord Nylon Thread-
Test No. 1

Individual Breaking Strengths of 50-lb, 6-Cord Nylon Thread-Test No. 1, lbs.

SAMPLE GROUP	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5
CONTROL-Dry	50.2	50.5	50.0	50.0	50.5
CONTROL-H_2O	50.7	50.0	49.7	48.0	50.2
CONTROL-Salt H_2O	51.5	51.7	50.5	52.2	51.2
CONTROL-pH=4 (HCl)	50.2	50.2	50.2	49.2	50.2
CONTROL-pH=10 (NaOH)	50.0	50.0	50.0	50.2	50.5
RUST-Dry	49.2	49.7	49.0	49.0	49.7
RUST-H_2O	48.2	49.0	50.0	50.0	50.5
RUST-Salt H_2O	46.7	48.0	51.0	50.7	44.0
RUST-pH=4 (HCl)	48.7	49.2	49.0	49.7	49.0
RUST-pH=10 (NaOH)	50.0	49.0	49.5	46.7	49.5
FERRIC OXIDE-Dry	49.2	49.5	49.2	49.5	49.0
FERRIC OXIDE-H_2O	48.5	49.0	48.0	49.0	46.0
FERRIC OXIDE-Salt H_2O	50.7	51.0	50.5	49.2	49.2
FERRIC OXIDE-pH=4 (HCl)	48.5	46.2	49.0	49.0	48.5
FERRIC OXIDE-pH=10 (NaOH)	48.2	48.5	49.0	48.7	49.2
FERRIC CHLORIDE-Dry	43.0	45.0	44.2	44.0	45.2
FERRIC CHLORIDE-H_2O	45.0	44.2	45.5	45.0	45.0
FERRIC CHLORIDE-Salt H_2O	45.7	45.0	42.7	46.0	44.7
FERRIC CHLORIDE-pH=4 (HCl)	42.5	40.0	42.0	43.0	43.0
FERRIC CHLORIDE-pH=10 (NaOH)	42.7	43.2	39.0	43.2	41.5

APPENDIX C.

Individual Breaking Strengths of
1.1-Ounce, Ripstop Nylon-
Test No. 2

Individual Breaking Strengths of 1.1 Ounce Ripstop Nylon-Test No. 2, lbs.

GROUP SAMPLE	1	2	3	4	5	6	7	8	9	10	11
CONTROL-Dry	51.5	52.0	52.2	53.0	51.0	50.5	52.0	51.7	50.7	50.0	----
CONTROL-H_2O	53.0	51.2	47.7	50.5	51.7	52.0	50.2	51.0	50.0	----	----
CONTROL-Salt	51.7	48.5	50.0	51.2	48.2	48.7	50.0	50.0	49.7	49.0	----
CONTROL-pH=4	51.0	51.0	51.2	51.0	51.7	51.5	49.5	52.0	50.0	50.0	----
CONTROL-pH=10	51.2	48.5	51.7	51.7	51.7	50.0	50.0	50.0	50.0	48.0	----
RUST-Dry	51.0	48.2	51.0	53.0	52.0	----	----	----	----	----	----
RUST-H_2O	51.5	50.5	52.2	51.0	----	----	----	----	----	----	----
RUST-Salt	52.2	51.0	51.2	51.2	50.5	51.2	----	----	----	----	----
RUST-pH=4	50.0	51.0	52.7	51.2	51.5	----	----	----	----	----	----
RUST-pH=10	----	----	----	----	----	----	----	----	----	----	----
FERRIC OXIDE-Dry	52.0	53.0	52.0	49.7	50.5	52.0	48.0	52.5	50.2	52.0	----
FERRIC OXIDE-H_2O	51.2	49.0	51.7	52.2	51.0	52.5	52.0	49.7	50.7	49.0	51.7
FERRIC OXIDE-Salt	51.7	53.7	53.7	52.0	50.0	53.2	52.5	52.7	53.2	51.0	----
FERRIC OXIDE-pH=4	52.2	52.5	51.7	52.5	52.0	53.0	52.0	52.0	52.2	51.2	53.0
FERRIC OXIDE-pH=10	52.5	52.2	50.7	49.7	52.7	51.0	53.0	53.5	51.7	----	----

TABLE I: Tabulated Results of Test I for 1.1 Ounce Ripstop Nylon

		BREAK STRENGTH (LBS.)		
	SAMPLE GROUP	RANGE	$\bar{x}$	σ
(1)	CONTROL-Dry	51.0-52.7	51.7	.61
	CONTROL-Distilled Water	51.2-53.2	52.4	.76
	CONTROL-Salt Water	45.0-56.2	50.9	4.40
	CONTROL-pH=4	51.2-52.5	51.8	.55
	CONTROL-pH=10	48.0-51.2	50.2	1.16
			$\bar{\bar{x}}_1 = 51.4$	$\sigma = .77$
(2)	IRON RUST-Dry	47.7-53.0	50.9	1.79
	IRON RUST-Distilled Water	46.0-51.5	48.5	2.07
	IRON RUST-Salt Water	53.0-55.0	54.1	.66
	IRON RUST-pH=4	51.2-53.2	52.7	.75
	IRON RUST-pH=10	48.2-53.0	51.1	1.88
			$\bar{\bar{x}}_2 = 51.5$	$\sigma = 1.86$
(3)	FERRIC OXIDE-Dry	49.0-52.0	50.9	1.00
	FERRIC OXIDE-Distilled Water	47.0-51.0	49.7	1.47
	FERRIC OXIDE-Salt Water	41.5-54.5	49.4	4.81
	FERRIC OXIDE-pH=4	38.7-52.5	48.0	4.82
	FERRIC OXIDE-pH=10	46.7-51.2	50.0	1.72
			$\bar{\bar{x}}_3 = 49.6$	$\sigma = .95$
			$\bar{\bar{\bar{x}}}_{1,2,3} = 50.8$	$\sigma = 1.56$
(4)	FERRIC CHLORIDE-Dry	32.0-39.0	34.5	2.65
	FERRIC CHLORIDE-Distilled Water	26.0-41.5	32.6	5.03
	FERRIC CHLORIDE-Salt Water	13.7-42.0	25.9	12.90
	FERRIC CHLORIDE-pH=4	17.5-40.7	27.0	9.13
	FERRIC CHLORIDE-pH=10	13.0-42.0	26.7	12.10
			$\bar{\bar{x}}_4 = 29.34$	$\sigma = 3.51$
			$\bar{\bar{\bar{x}}}_{1,2,3,4} = 45.5$	$\sigma = 9.56$

TABLE II: Tabulated Results of Test I for 50-Pound, 6-Cord Nylon Thread

	BREAK STRENGTH (LBS.)		
SAMPLE GROUP	RANGE	$\bar{x}$	σ
(1) CONTROL-Dry	50.0-50.5	50.2	.23
CONTROL-Distilled Water	48.0-50.7	49.7	.92
CONTROL-Salt Water	50.5-52.2	51.4	.56
CONTROL-pH=4	49.2-50.2	50.0	.40
CONTROL-pH=10	50.0-50.5	50.1	.20
		$\bar{\bar{x}}_1 = 50.3$	$\sigma = .58$
(2) IRON RUST-Dry	49.0-49.7	49.3	.32
IRON RUST-Distilled Water	48.2-50.5	49.5	.83
IRON RUST-Salt Water	44.0-51.0	48.1	2.61
IRON RUST-pH=4	48.7-44.7	49.1	.33
IRON RUST-pH=10	46.7-50.0	48.9	1.17
		$\bar{\bar{x}}_2 - 49.0$	$\sigma = .48$
(3) FERRIC OXIDE-Dry	49.0-49.5	49.3	.20
FERRIC OXIDE-Distilled Water	46.0-49.0	48.1	1.11
FERRIC OXIDE-Salt Water	49.2-51.0	50.1	.7[illegible]
FERRIC OXIDE-pH=4	46.2-49.0	48.2	1.04
FERRIC OXIDE-pH=10	48.2-49.2	48.7	.40
		$\bar{\bar{x}}_3 = 48.9$	$\sigma = .74$
		$\bar{\bar{\bar{x}}}_{1,2,3} = 49.4$	$\sigma = .88$
(4) FERRIC CHLORIDE-Dry	43.0-45.2	44.3	.79
FERRIC CHLORIDE-Distilled Water	44.2-45.5	44.9	.42
FERRIC CHLORIDE-Salt Water	42.7-46.0	44.8	1.16
FERRIC CHLORIDE-pH=4	40.0-43.0	42.1	1.11
FERRIC CHLORIDE-pH=10	39.0-43.2	41.9	1.59
		$\bar{\bar{x}}_4 = 43.6$	$\sigma = 1.32$
		$\bar{\bar{\bar{x}}}_{1,2,3,4} = 47.9$	$\sigma = 2.70$

TABLE III: Tabulated Results of Test II-1.1 Ounce Ripstop Nylon

	BREAK STRENGTH (LBS.)		
SAMPLE GROUP	RANGE	$\bar{X}$	σ
(1) CONTROL-Dry	50.0-53.0	51.5	.86
CONTROL-Distilled Water	47.7-53.0	50.8	1.41
CONTROL-Salt Water	48.2-51.7	49.7	1.08
CONTROL-pH=4	49.5-52.0	50.8	.72
CONTROL-pH=10	48.0-51.7	50.3	1.25
		$\bar{\bar{X}}_1 = 50.6$	$\sigma = .60$
(2) IRON RUST-Dry	48.2-53.0	51.0	1.60
IRON RUST-Distilled Water	50.5-52.2	51.3	.63
IRON RUST-Salt Water	50.5-52.2	51.2	.50
IRON RUST-pH=4	50.0-50.7	51.3	.87
IRON RUST-pH=10	---------	----	----
		$\bar{\bar{X}}_2 = 51.2$	$\sigma = .12$
(3) FERRIC OXIDE-Dry	48.0-53.0	51.2	1.17
FERRIC OXIDE-Distilled Water	49.0-52.5	51.0	1.19
FERRIC OXIDE-Salt Water	50.0-53.7	52.3	1.15
FERRIC OXIDE-pH=4	51.7-53.0	52.3	.43
FERRIC OXIDE-pH=10	49.7-53.5	51.9	1.15
		$\bar{\bar{X}}_3 = 51.7$	$\sigma = .55$
		$\bar{\bar{\bar{X}}}_{1,2,3} = 51.2$	$\sigma = .68$

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